AIR QUALITY AND THE CHESAPEAKE BAY

- Briefing Paper for the Chesapeake Bay Watershed Blue Ribbon Finance Panel -

Introduction

The Chesapeake Bay Program has estimated that atmospheric deposition contributes about 25 to 32 percent of the anthropogenic nitrogen load delivered to the Chesapeake Bay and tidal tributaries, or roughly 76-98 million pounds per year (2000 estimate). This paper discusses the Chesapeake Bay Program's history and approach to assessing atmospheric deposition as a component of the Bay's excess nutrient problem and the relationship of Clean Air Act (CAA) regulations and actions to Bay cleanup efforts.

The Bay benefits from Clean Air Act implementation, and this paper will show how nitrogen reductions attributable to CAA regulations have been calculated and included in the current Chesapeake Bay Program tributary strategies to meet the 2010 goal for restoring the water quality of the Bay and its tidal tributaries. No costs for achieving the current regulatory requirements have been included in the funding needs which the Panel is now addressing; the reasoning is that the regulations were promulgated to achieve better air quality and protect human health, and the Bay is a collateral beneficiary.

Chesapeake Bay Program partners could seek to establish voluntary air emission reduction programs or state-specific requirements for individual sources which go beyond CAA regulations in order to accelerate Bay water quality improvements. However, evaluation of the costs and benefits of such initiatives has been significantly hampered by the lack of feasible and appropriate modeling tools. New tools are being developed, but it will be awhile before they are completed and in use.

Background: the importance of reducing nutrient loads to the Chesapeake Bay

From its inception in 1983, the Chesapeake Bay Program has understood that reducing nutrient loads (nitrogen and phosphorous) is the key to protecting and restoring water quality and living resource habitat in the Chesapeake Bay and its tidal tributaries. The five-year Chesapeake Bay research study conducted by the U.S. Environmental Protection Agency (EPA) during the 1970s examined many possible causes for the decline in the Bay's quality and resources, and concluded that all the evidence pointed to nutrient over-enrichment, or eutrophication. In particular, nutrient over-enrichment causes excess algal growth, leading to periods of low or no dissolved oxygen in portions of the Bay, and inhibiting the growth of underwater grasses, an essential habitat and food source. Globally, human activities (energy and food production) have doubled the rate of formation of reactive nitrogen compounds over natural rates.

In 1987, the Program's governing body, the Chesapeake Executive Council, agreed to its first numerical goals for nutrient reduction – a commitment to reduce, by 2000, both nitrogen and phosphorous loads to the Bay by 40% and to maintain these reduced levels thereafter. In 1992, the Council signed an amendment to the 1987 agreement specifying that the jurisdictions

(Maryland, Virginia, Pennsylvania and the District of Columbia) would develop tributary-specific strategies to achieve the nutrient reduction goals.

Under the Program's current master agreement, *Chesapeake* 2000, a new generation of tributary strategies is underway to meet the stringent nutrient and sediment allocations adopted in 2003 to restore water quality in the Bay and tidal tributaries by 2010. These tributary strategies will, for the first time, cover all of the Chesapeake Bay watershed as the headwater states of Delaware, New York and West Virginia have joined the original Bay jurisdictions in the water quality restoration effort. While the first generation of tributary strategies did not consider atmospheric deposition, the partners are now including air emission controls from Clean Air Act regulations in the second-generation tributary strategies, and are developing new modeling tools to evaluate further emission control options.

Recognizing a role for the Clean Air Act

The 1987 Chesapeake Bay agreement included an objective to "quantify the impacts and identify the sources of atmospheric inputs on the Bay system." In the 1992 amendment, the Council stated that the Program's nutrient reduction strategies would "include an air deposition component, which builds upon the 1990 amendments to the federal Clean Air Act and explores additional implementation opportunities to further reduce airborne sources of nitrogen entering Chesapeake Bay and its tributaries."

The nitrogen load which the Chesapeake Bay Program seeks to reduce is not nitrogen gas (N_2) but reactive nitrogen compounds. In fact, the objective of many nutrient reduction processes and technologies is to liberate nitrogen from its compounds and release it back to the atmosphere as N_2 (denitrification). Airborne nitrogen deposits both directly onto tidal waters of the Bay and onto the watershed's land and tributary streams, where some fraction is subsequently transported to the Bay. An additional contributor, which is not well-quantified, is deposition to the coastal ocean and subsequent transport into the Bay.

The atmospheric nitrogen compounds which have received the most consideration are oxidized nitrogen - as nitric acid and nitrate ion - a typical byproduct of fossil fuel combustion; and reduced nitrogen - ammonia and ammonium - a typical byproduct of agricultural activity, as well as many other sources. Naturally-occurring organic nitrogen compounds, such as amines in pollen, also contribute to the load. In 2000, the Chesapeake Bay Program estimated that the relative amounts of oxidized, reduced and organic nitrogen deposited on the watershed were 68%, 20% and 12%, respectively.

The following sections describe (1) how the Chesapeake Bay Program has taken information from Clean Air national modeling (informed by air monitoring and source assessments) to determine loads of nitrogen delivered to the Bay watershed and thence to Bay tidal waters from various source categories; and (2) how reductions in emissions of oxides of nitrogen (NOx) mandated by federal CAA regulations have been incorporated as reductions in nitrogen loads in the new tributary strategies.

As a general matter, it is important to highlight several differences in how the Clean Air

Act and the Chesapeake Bay Program think about airborne sources. The first is to note that the objective of CAA regulations and actions is to improve air quality, especially for protection of human health. The objective of the Chesapeake Bay Program is to protect and restore the living resources (principally aquatic life) of the Bay and its tributaries. Thus, while the Bay Program can benefit from CAA regulations, protection of Bay water quality and aquatic resources is not a driving factor in determining which air pollutants to regulate, or how to approach the task.

Of the several compounds of nitrogen which contribute to nutrient over-enrichment of Bay tidal waters, CAA regulations have focused on reducing emissions of NOx, principally nitric oxide, which is a precursor of ozone, nitric acid and nitrate. Other nitrogen compounds of concern to the Bay, like ammonia and ammonium, are largely unregulated by the Clean Air Act at present. This is the case even though ammonia contributes to the formation of "fine particulates", a CAA criteria pollutant.

The third point of distinction is that, except for acid rain, the Clean Air Act focuses on assessing and reducing *pollutants in the air.* The Bay Program's concern is *deposition,* that is, where and in what quantities the air pollutants (nitrogen compounds, in this case) are deposited to water and land areas within the Bay watershed and contribute to nitrogen loads to the Bay through runoff, or are deposited directly to the tributary rivers and the Bay.

Calculating the airborne nitrogen load to the Chesapeake Bay watershed

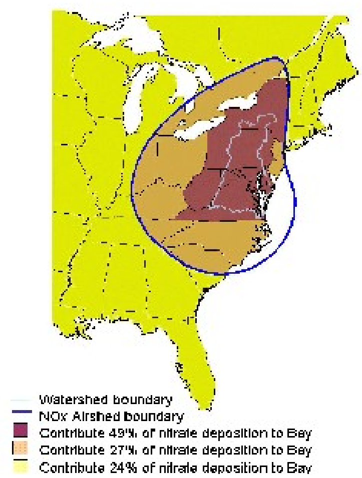
Air quality models: use and limitations. The Chesapeake Bay Program has relied to date on EPA's national air quality models (the Regional Acid Deposition Model or RADM and more recently the Community Multi-scale Air Quality or CMAQ model) to calculate the amount of airborne nitrogen from air emission sources deposited on the lands and waters of the Chesapeake Bay Basin. The modeling provides estimates of both NOx and ammonia air deposition. Modeling the atmospheric processes (source emissions to deposition in the Bay watershed) has been complex and time-consuming. With the national air quality model, emissions in a 37-state modeling domain are transported, transformed and deposited onto the landscape. The model does not keep track of individual sources but lumps emissions into categories or sectors (such as electricity generating units, on-road mobile sources, etc.).

Monitoring information to evaluate the air models comes from about 230 wet deposition monitoring stations in the National Atmospheric Deposition Program (NADP). Additional data are provided by the roughly 70 stations in the Clean Air Status and Trends Network (CASTNet).

Even with its limitations, the national air model has provided a good assessment of the deposition of NOx and ammonia emissions in the Chesapeake Bay watershed. In 2001, an extended version of RADM was used to calculate changes in NOx/nitrate deposition which might result from several actual and hypothetical air emission control scenarios.

The Chesapeake Bay watershed is 64,000 square miles, but the area from which it receives nitrogen compounds via air deposition (or the "airshed") is much larger. Figure 1 shows this relationship for nitrate deposition. About 49% of the deposition is from air emission sources located in the Bay watershed states.

Figure 1: Areas of NOx Emissions that Contribute Nitrogen Deposition to the Chesapeake Bay and Its Watershed



Use of the CBP Models: calculating nitrogen loads delivered to the Bay. Upon receiving the air deposition calculations from the air model, the Chesapeake Bay Program uses the Water Quality and Watershed Models to calculate the water quality impact of both the atmospheric nitrogen deposited to the watershed and transported to the Bay and the direct deposition load onto the Bay and its tidal tributaries. Of the 463 million pounds estimated to have been deposited in the year 2000, about 20 million pounds were deposited directly to the waters. For the remaining 443 million pounds of nitrogen deposited, the Chesapeake Bay Program Watershed Model (WSM) calculated that only 56-78 million pounds were transported from the watershed to the Bay.

Atmospheric deposition in the Chesapeake watershed is, on average, about 10.3 pounds/acre. Land use and implementation of best management practices have a major impact on the amount of airborne nitrogen which reaches Bay waters. The amount of forest land has the greatest impact, and the Chesapeake Bay watershed is 58% forested. Generally, the forests in the Chesapeake Bay watershed are not nitrogen-saturated, which means that they have the capacity to take up airborne nitrogen and prevent a significant portion from reaching either tidal or non-tidal waters. About 76% of the atmospheric nitrogen load to forests is attenuated by forest plant uptake, denitrification and soil storage, and the WSM estimates the average nitrogen export from forests at 2.5 pounds/acre. By contrast, there is very little reduction of airborne nitrogen loads when they are deposited on developed urban areas with highly impervious surfaces; the WSM estimates that only 20% of the atmospheric nitrogen load is attenuated in urban impervious areas and 80% reaches the water.

As shown by the examples above, the Chesapeake Bay Program's Watershed Model accounts for terrestrial processes in estimating the load of airborne nitrogen reaching the tidal waters of the Bay. Different processes for nutrient uptake or sequestration, and rates of runoff, have been calculated for the land uses included in the WSM (such as forest, agricultural land, mixed open land such as golf courses, urban impervious land) in an effort to represent, as accurately as possible, how nitrogen compounds deposited on the land arrive to the Bay and its tidal tributaries. In addition to land uses, different urban and agricultural land management practices can also affect the atmospheric load calculations.

This analytical capability is sophisticated and unique to the Chesapeake Bay Program. To interpret the modeled estimates of nitrogen loads to the Bay from air deposition to the watershed, it is essential to know the basis for the land use calculations (e.g. census year) as well as how the estimates of best management practices (BMPs) on the lands were made. The Program jurisdictions compile annual reports on implementation of BMPs (the term is used broadly here to indicate all types of nutrient control employed by point or non-point sources), and the WSM uses estimates of BMP efficiency developed by Chesapeake Bay Program expert work groups in making its calculations.

Figure 2 shows the 2000 estimate of total atmospheric nitrogen deposition to the Chesapeake Bay watershed (based on the RADM model) contrasted with: the WSM estimate of nitrogen delivered to the Bay and tidal tributaries from deposition to land, and the amount deposited directly to the Bay tidal waters. The WSM calculation is based on estimated 2000 land use data and uses the 2000 compilation of BMPs implemented. In 2000, the Bay Program estimated that nitrogen loads from air deposition accounted for 25%-32% of the total nitrogen load to the Bay and its tidal tributaries. The higher estimate was used to calculate the totals shown in Figures 2 and 3 for atmospheric deposition.

Figure 2: Total Nitrogen Deposition Versus Delivered Load

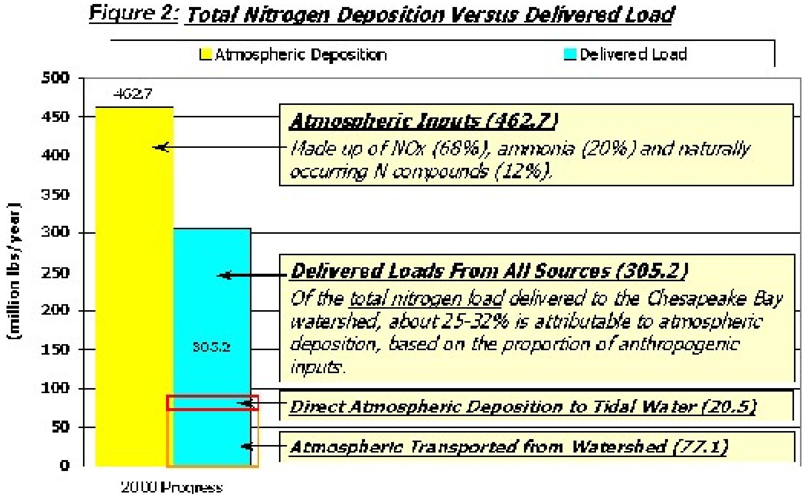
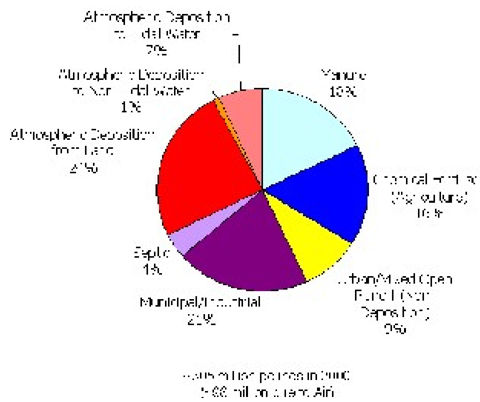


Figure 3 shows all nitrogen sources, and their relative contribution to nitrogen loads to the Bay in 2000 – distinguishing atmospheric loadings from other sources. When presenting watershed loads, the Bay Program often uses another pie chart where the atmospheric loading from the land is incorporated into the land use category where the deposition occurs.

Figure 3: Relative Contribution of Sources of Nitrogen Loads to the Bay in 2000



Chesapeake Bay Program evaluation of alternative CAA control scenarios

Several scenarios were evaluated in 2001, using RADM and WSM, for controlling NOx air emissions and estimating the benefits in terms of reduced nitrogen deposition and nitrogen loads to the Bay. These "Clean Air Act Nitrogen Oxides (NOx) Scenarios" were developed by a work group of air experts, and were part of a broader assessment conducted for protecting Shenandoah National Park. They included two packages of CAA regulatory actions, a hypothetical scenario with more aggressive regulatory actions, and a scenario which represented the "limits of technology" going well beyond contemplated federal regulatory actions and including voluntary or incentive-based controls. The scenarios are presented in Figure 4 (on the next page).

Figure 4: Clean Air Act Nitrogen Oxides (NOx) Scenario Descriptions

Scenario 1 "2007/2010 Base with NOx SIP"
This model run is the Basic 1990 Clean Air Act projected for the year 2010. This scenario includes regulations that have passed.
2007 non-utility and area source emissions.
2007 mobile source with Tier II tail-pipe standards on light duty vehicles.
2010 utility emissions: Title IV (Acid Rain Program) fully implemented; the 20-state NOx SIP call reductions @ 0.15#/Mmbtu. This would be during the ozone season only (May to September).

Scenario 2 "2020 CAA: With Tier II & Heavy Duty Diesel Regulations"
This model run includes Scenario 1, PLUS new heavy duty diesel regulations.
2020 non-utility and area source emissions (no additional controls).
2020 mobile source with Tier II tail pipe standards on light duty vehicles (which are now more effective), and heavy duty diesel standards to further reduce NOx emissions.
2020 utility emissions described in Scenario 1.

Scenario 3 "2020 CAA with Aggressive Utility Controls"
This model run includes Scenario 2, PLUS stringent new utility reductions in SO_2 and NOx.
2020 non-utility and area source emissions (Same as Scenario 2).
2020 mobile source with Tier II tail pipe standards on light duty vehicles (now more effective), and heavy duty diesel standards to further reduce NOx. (Same as Scenario 2).
2020 utility emissions with major reductions in SO_2 (90% reduction) and further NOx reductions through 2 paths: utilities go to 0.10#/Mmbtu for the entire year. No longer just seasonal reductions.

CAA with Aggressive Utility Controls and Industry-Point and Mobile Controls" This would be Chesapeake Bay's "Limit of Technology" Scenario.
This model run includes Scenario 3, PLUS reductions in non-utility source emissions and mobile source emissions.
2020 non-utility (industrial) point emissions cut almost in half for both SO_2 and NOx.
2020 area source emissions (same as in Scenarios 2 & 3).
2020 mobile source: heavy duty diesel standards to further reduce NOx, PLUS super ultra-low emission vehicle assumed for light duty vehicles.
2020 utility emissions with annual reductions as described in Scenario 3.

To develop the basic approaches and tools for implementing the nutrient and sediment reduction commitments of *Chesapeake 2000*, an ad hoc, high-level Water Quality Steering Committee (WQSC) was established. In October 2002, one of the WQSC's tasks was to review the estimated benefits of these Clean Air Act NOx reduction scenarios, and consider which would be included in the "tiers" of nutrient reduction actions for assessing how to attain the new water quality criteria.

Four "tiers" or packages of actions were constructed by the WQSC, and the results modeled to estimate the level of control that would be necessary to meet the Bay water quality criteria. Cost estimates were also developed by EPA and the state agencies. The conclusions of the WQSC about how to construct the "tiers" are highly relevant to the deliberations of the Blue Ribbon Panel, because the actions comprising "Tier 3" were used by the Chesapeake Bay Commission in making its cost estimates for restoring Bay water quality by 2010, published in

The Cost of a Clean Bay.

The discussion of the CAA NOx reduction scenarios by the WQSC focused on the practicality of their being implemented in time to contribute to meeting the 2010 Bay water quality objective. CAA Scenario 1 was clearly important to include, as it represented the benefits of CAA regulations already promulgated and scheduled to be implemented before 2010. The NOx emission reductions in CAA Scenario 1 will provide an estimated 11 million pound reduction in nitrogen load to the Bay by 2010. CAA Scenario 2 was also selected for inclusion in the reductions considered to be "attainable" (Tier 3), although the requirements have post-2010 implementation schedules. By 2020, these two scenarios will provide an estimated 18 million pound reduction in nitrogen loads to the Bay (calculation based on 2000 land uses).

The estimated reductions in nitrogen loads attributable to the air quality regulations in CAA Scenario 1 have been distributed to the tributary watersheds, and included in the new tributary strategies. CAA Scenario 2, also consisting of promulgated regulations, was not included in the tributary strategies because the load reduction benefits will be realized after 2010. However, both sets of CAA regulatory requirements will make an important contribution to Bay water quality.

Recently, EPA promulgated another CAA regulation that will further reduce atmospheric nitrogen loads in the Chesapeake Bay watershed by 2030. The "Clean Air Nonroad Diesel Rule" complements the vehicle emission controls included in CAA Scenarios 1 and 2, by controlling particulate and NOx emissions from nonroad diesel-powered vehicles such as bulldozers and farm tractors.

Unlike all the other control actions included in the WQSC's attainability analysis, the CAA Scenarios were **not** costed out by the Chesapeake Bay Program. Their costs were **not** included in the Chesapeake Bay Commission's publication, *The Cost of a Clean Bay*. Nor were the costs of implementing the CAA Scenarios calculated in the EPA's *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*. The WQSC reasoned that CAA Scenarios had been or would be enacted as regulations based on their air quality benefits, and that the costs of achieving the required air pollutant reductions would be borne by the owners of the air emission sources – located in a far wider area than just the Chesapeake Bay watershed. (Cost estimates for meeting CAA requirements are commonly estimated when regulations are being considered, although it may be difficult to distinguish costs for sources located within the Bay watershed. This issue can be developed further should Panel members wish.)

EPA's "adoption" of a nitrogen reduction target

In March 2003, the Chesapeake Bay Program's Principals' Staff Committee (PSC) met to adopt the new nutrient load allocations required by *Chesapeake 2000*. Based on the extensive analyses conducted for the WQSC, the jurisdictions knew they had to make hard, and expensive choices. Generally, all agreed that achieving nutrient reductions at the level of Tier 3 would be attainable, but there was significant concern about achieving reductions beyond that level. Yet the modeling indicated that the water quality criteria were not met everywhere and at all times in the Bay main stem, even at the Tier 3 level of implementation.

The EPA Clean Air program (using a model called Regional Modeling System for Aerosols and Deposition or REMSAD) had worked with the Chesapeake Bay Program to estimate the nitrogen reduction benefits which might accrue from enactment of the Clear Skies legislative proposal. According to the model analysis, using REMSAD and Chesapeake Bay Program's WSM, the NOx cap and trade system authorized by Clear Skies would produce an estimated 8 million pound reduction in the annual nitrogen load to the Bay by 2010, and10 million pounds by 2020 – a substantial addition to the reductions already expected from implementation of the existing CAA regulations in Scenarios 1 and 2. Based on this analysis, EPA agreed at the PSC meeting to take responsibility for an 8 million pound annual reduction in nitrogen loads, based on enacting Clear Skies. With this agreement, the PSC adopted a nitrogen allocation of 175 million pounds annually, to be met by 2010.

In the year since March 2003, legislative progress on the Clear Skies Act has stalled. In response, the EPA Administrator has proposed a new Clean Air Interstate Rule (also known as the Interstate Air Quality Rule) in the hope that many of the air emission reductions in the Clear Skies legislation could be accomplished instead through regulatory action. The rule would reduce emissions of SO_2 and NOx in 29 eastern states and the District of Columbia, in two phases. While the jurisdictions are completing their tributary strategies, EPA is analyzing the benefits to the Bay of the NOx reductions which would be achieved by this proposed regulation. Computer modeling results will be available in late summer 2004. If the proposed Clean Air Interstate Rule provisions are not sufficient to meet EPA's 8 million pound annual reduction allocation, EPA will work with its Chesapeake Bay Program partners to identify additional "gap closing" measures that will achieve the necessary reductions.

Achieving air emission reductions beyond CAA regulations

As the tributary strategies are being done, there is much interest in being able to evaluate the benefits of air emission reductions which could occur without federal regulations, whether on a state-regulated or voluntary basis, and considering how nutrient trading and financial incentives might apply. The lack of appropriate modeling tools for estimating the air deposition reductions from such actions has been a real stumbling block. Unless the results of nutrient load reduction actions can be modeled, they cannot be included in tributary strategies. Thus, to date, no actions to reduce air emissions beyond the CAA regulatory scenarios have been included in CBP tributary strategies.

Due to the nature and structure of the national air quality model, the Chesapeake Bay Program cannot make effectively a direct association between an emission reduction at a specific source and the consequent reduction of nitrogen load to the Bay. This is a challenge which the Bay Program has begun to tackle. Through the Maryland Department of Natural Resources, a tracking tool is being developed which can make the association between an emission source and its relative contribution to nitrogen loads in the Bay. A component is a model being developed by EPA Region III, with Chesapeake Bay Program funding, that will allow the Program partners to assess voluntary and state-specific options taken to reduce nitrogen emissions.

While most of the attention has been on reduction of NOx emissions, sources of ammonia/ammonium are also significant, especially those associated with concentrated livestock operations. There are no current CAA regulations driving down ammonia emissions, and existing ammonia emission inventories are poor. Bay Program partners would like to evaluate installation of voluntary controls on ammonia emissions from agricultural activities and urban environments. The next round of Chesapeake Bay Program model development, to be complete in 2007, will include a better representation of ammonia loads through the use of the more detailed air model CMAQ.

Summary for the Blue Ribbon Panel

1. The Chesapeake Bay Program has a significant interest in furthering air emission reductions of nitrogen oxides and ammonia/ammonium because air deposition of nitrogen compounds contributes an estimated 25-32% of the nitrogen load to the Bay.

2. The new tributary strategies include reductions attributable to Clean Air Act regulatory actions described as Scenario 1 above. EPA has proposed new NOx emission controls in the Clean Air Interstate Rule, which could contribute to nitrogen reductions before 2010. The Agency is in the process of calculating the benefits of this rule for reducing nitrogen input to the Bay.

3. The Bay Program partners are not satisfied with relying solely on CAA federal regulations to obtain reduction of nitrogen air emissions. They would like to evaluate voluntary initiatives, nutrient trading and state-specific regulatory initiatives that would allow them to go beyond federal requirements. Modeling tools are being developed to allow evaluation of a wide range of air emission control options. Their use, however, is about a year away.

4. No costs for achieving the load reductions attributed to these Clean Air Act regulations have been included in the Bay Program's calculation of funding needs, based on the assumption that the regulatory air emission controls would be implemented anyway.

Question to the Panel: Are there financial incentives which are warranted and practicable which could accelerate the pace of regulatory controls and which the Bay Program should assess?